UMass Update For CA DWR 7/28/2014

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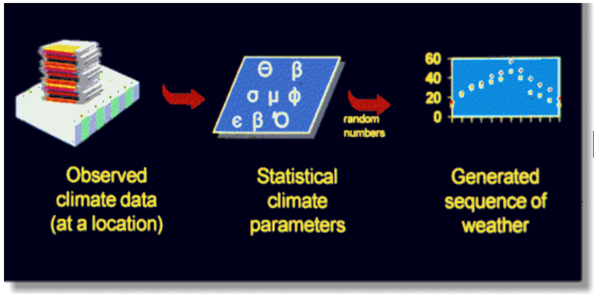
Steps

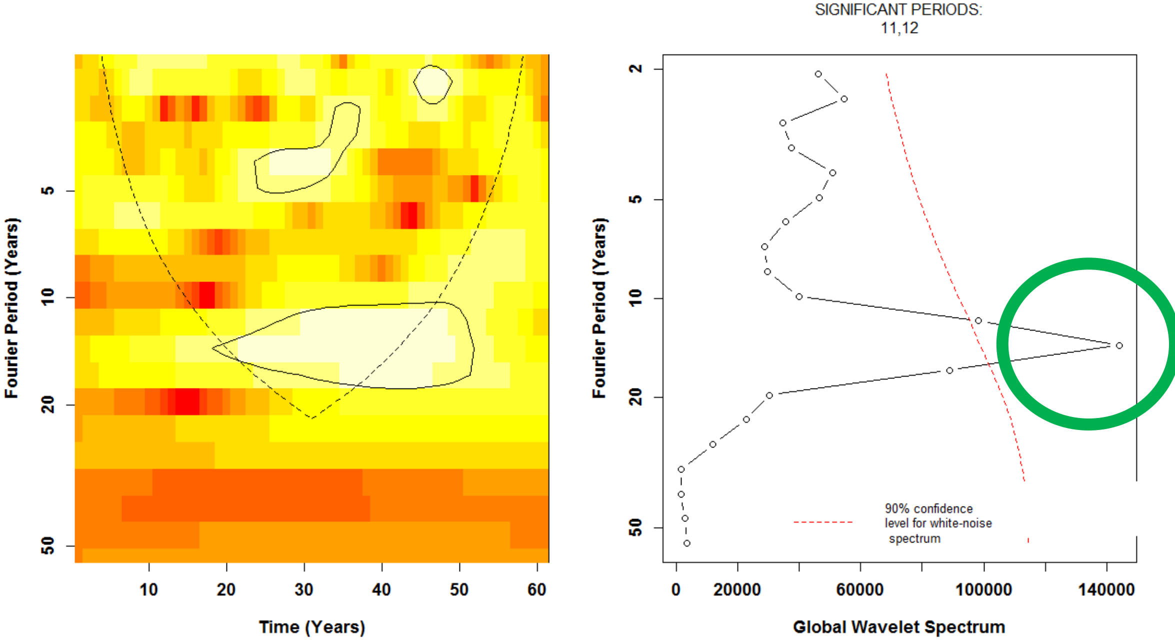
- Stakeholder consultation to understand system function, system risks, and set performance thresholds, among other things.
- Modeling steps:
  - 1) Diagnose historical low frequency variability
  - 2) Develop and calibrate the hydrologic model
  - 3) Perform the climate risk assessment
  - 4) Perform experiments in climate risk management

STEP 1: DIAGNOSIS OF HISTORICAL LOW-FREQUENCY VARIABILITY

Wavelet Auto-Regressive Model & K-Nearest Neighbor & Disaggregation: R Statistical Package



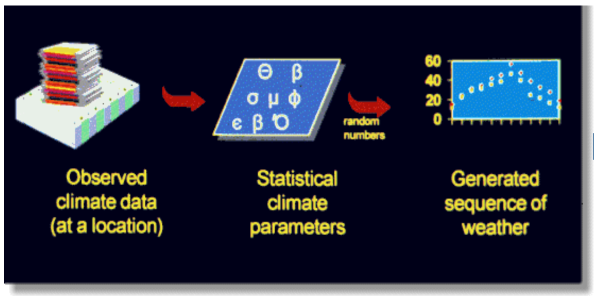
Wavelet Analysis of Area-Averaged Annual California Precipitation



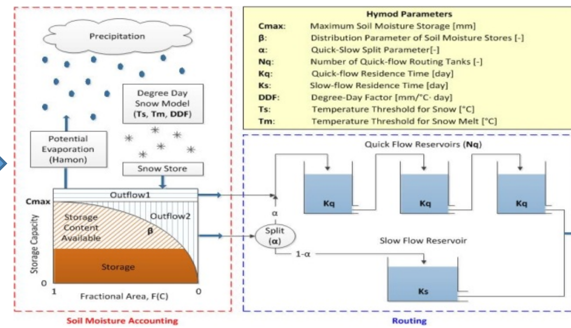
1950 2010

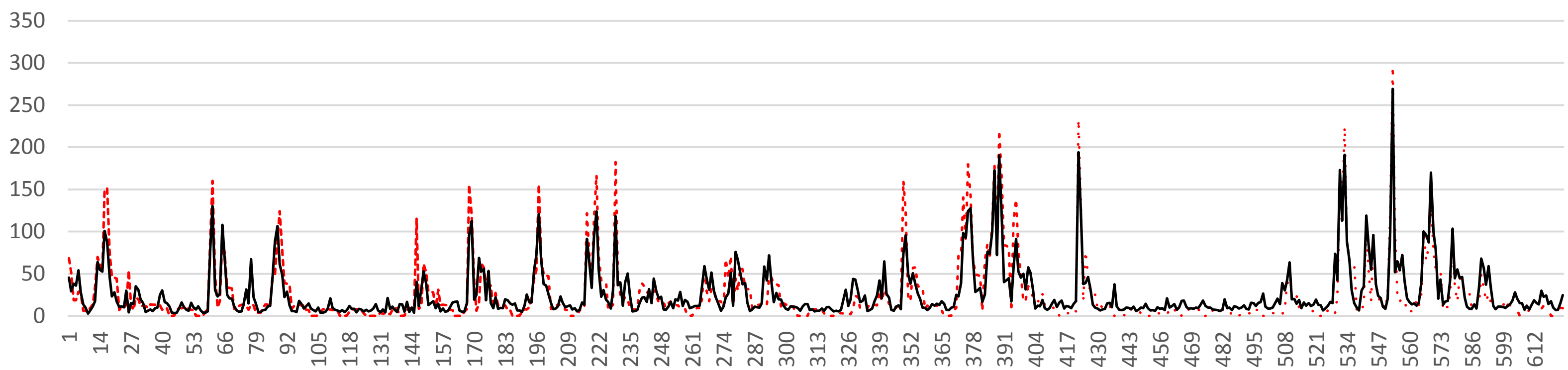
STEP 2: HYDROLOGIC MODEL DEVELOPMENT AND CALIBRATION

Wavelet Auto-Regressive Model & K-Nearest Neighbor & Disaggregation: R Statistical Package



Hydrologic Model: VIC or Sacramento

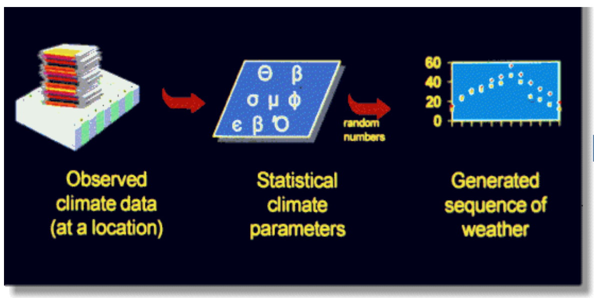




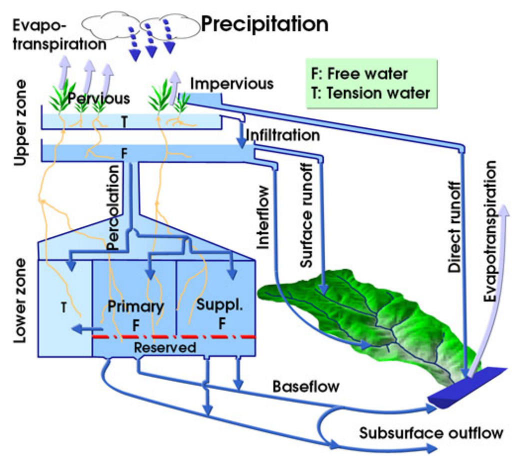
STEP 3: CLIMATE RISK ASSESSMENT

Explore the vulnerabilities of the current system design

Wavelet Auto-Regressive Model & K-Nearest Neighbor & Disaggregation & Climate Trends: R Statistical Package



Hydrologic Model: VIC or Sacramento



Systems model: CalLite

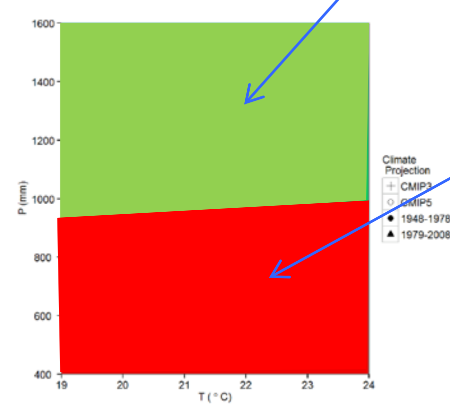
Many runs [e.g., 780 times (13 precip permutations, 6 temp, 10 stochastic realizations of each)]

Next:

1) Add climate change projections to the climate response map
2) Make judgment call regarding risks
3) Consider adaptations

Robust

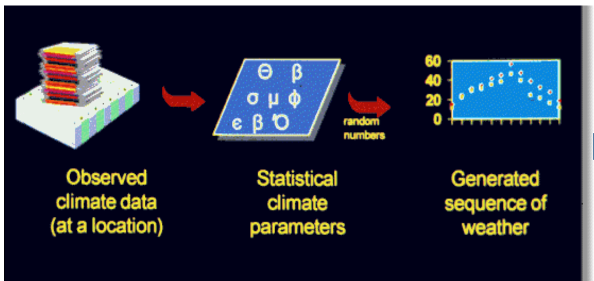
Climate-vulnerable



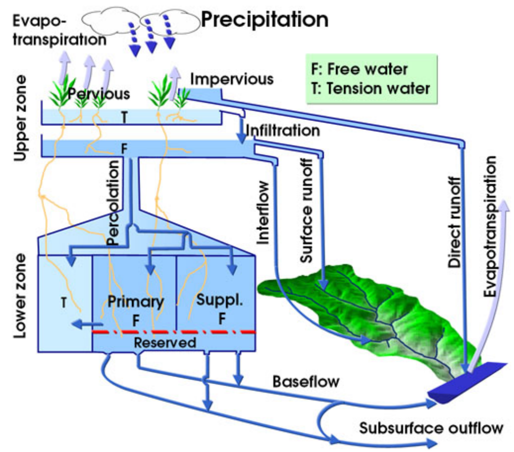
STEP 4: CLIMATE RISK MANAGEMENT

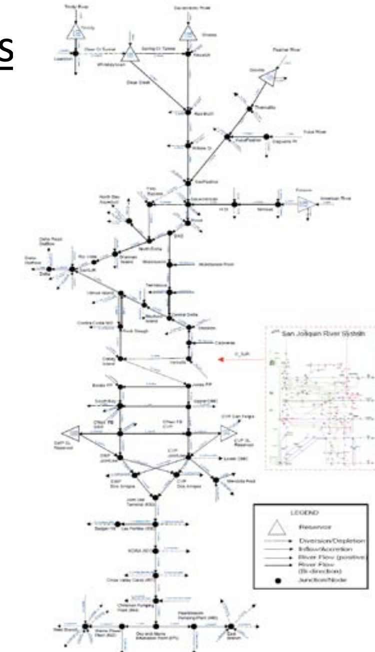
Explore the ability of various design modifications to reduce system ris

Wavelet Auto-Regressive Model & K-Nearest Neighbor & Disaggregation & Climate Trends: R Statistical Package



Hydrologic Model: VIC or Sacramento





Systems model: CalLite

Many runs [e.g., 3900 times (5 design modifications, 13 precip permutations, 6 temp, 10 stochastic realizations of each)]

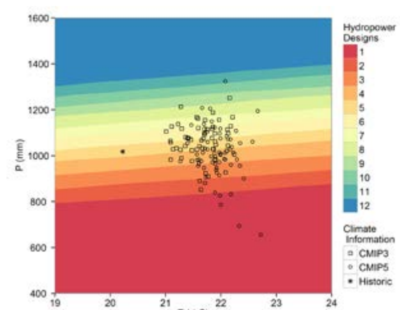
Decision-influencing choices

Example decision metrics

Reservoir storage in flood season (Dec-Mar)
April 1 carryover storage
% of years vulnerable to interruptions

Example likelihood concepts

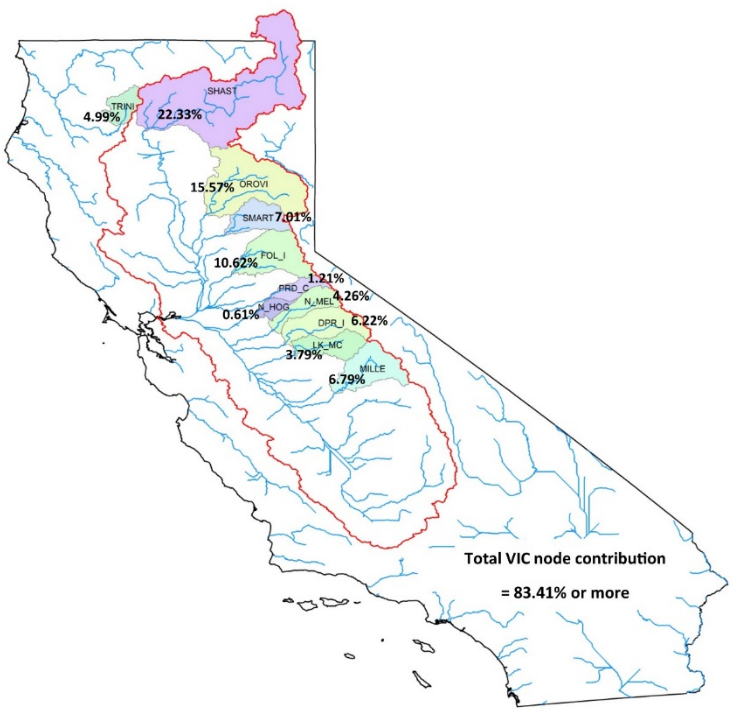
Probability = fraction of GCM projections encompassed, weighted according to similarity
Probability = fraction of non-discountable climate envelope encompassed
Probability = bivariate normal pdf on climate change space



Hydrologic Model

Calibration of VIC routing model and demonstration of benefits of proposed switch to Sacramento

CalLite Inflow from VIC



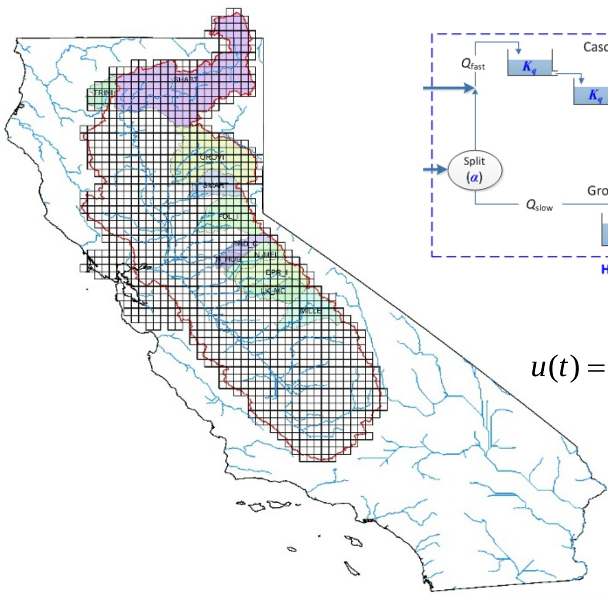
Original VIC Simulations from California DWR

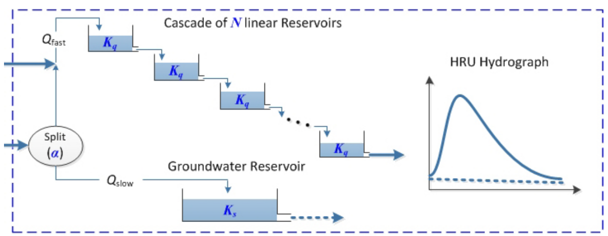
VIC Basin	Notes	NSE
FOL_I	Good correlation	0.82
LK_MC	Good correlation	0.89
N_MEL	Good correlation	0.81
MILLE	Decent correlation	0.56
PRD_C	It looks like the location of the VIC and CalLite does not match up	-1.20
N_HOG	VIC inflow significantly higher than CalLite	-629
OROVI	Good correlation	0.88
DPR_I	Good correlation	0.76
SHAST	Decent correlation	0.87
TRINI	No VIC data	-
SMART	VIC overestimate CalLite flow	-0.42

$$\text{Nash Sutcliffe Efficiency} = 1 - \frac{\sum_{i=1}^{n}\left(Obs_i^j - Sim_i^j\right)^2}{\sum_{i=1}^{n}\left(Obs_i^j - \overline{Obs}^j\right)^2}$$

VIC Simulation Improvement

VIC → In-grid Routing

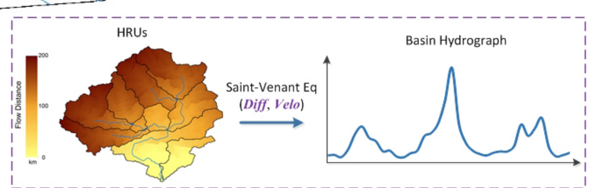




HRU Flow Routing using Nash Cascade UH

$$u(t) = \frac{K}{\Gamma(N)}(Kt)^{N-1}\exp(-Kt)$$

River Routing



Basin Channel Routing using Linearized Saint-Venant Eq

$$\frac{\partial Q}{\partial t} + C\frac{\partial Q}{\partial x} - D\frac{\partial^2 Q}{\partial x^2} = 0$$

All Improved except OROVI

All Acceptable except PRD_C

Improved VIC from Routing Calibration

VIC Basin	NSE From CA DWR	NSE After Routing Calibration
FOL_I	0.82	**0.84**
LK_MC	0.89	**0.90**
N_MEL	0.81	**0.84**
MILLE	0.56	**0.65**
PRD_C	-1.20 (Unacceptable)	**0.37**
N_HOG	-629 (Unacceptable)	**0.65**
OROVI	0.88	0.88
DPR_I	0.76	**0.82**
SHAST	0.87	**0.91**
TRINI	-	**0.82**
SMART	-0.42 (Unacceptable)	**0.70**

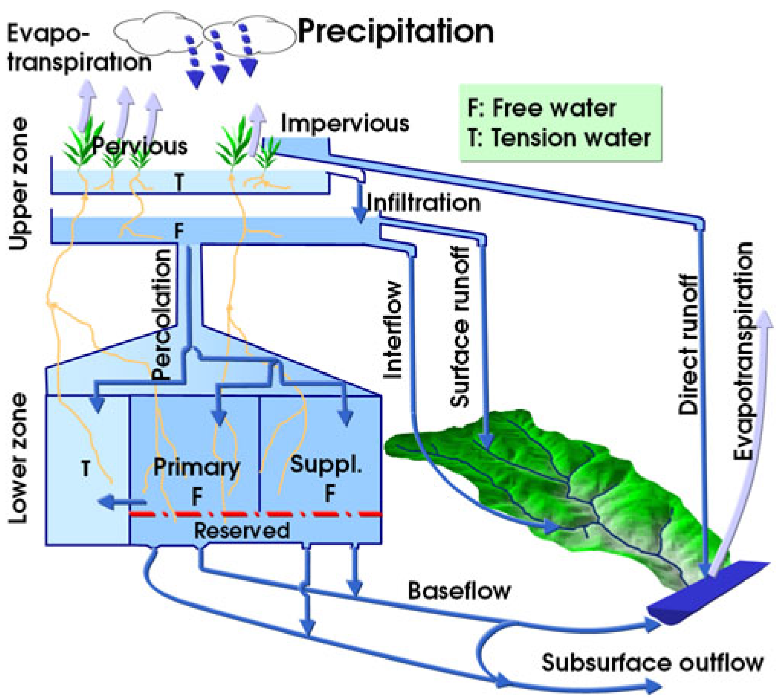
4 parameters related to Nash Cascade UH and Saint-Venant River Routing are calibrated with a automatic calibration process (Genetic Algorithm)

CallLite Inflow from SAC-SMA

Original VIC < VIC with improved routing < SAC-SMA

23% of inflow to CalLite – Big Improvement Here

SAC-SMA + SNOW17



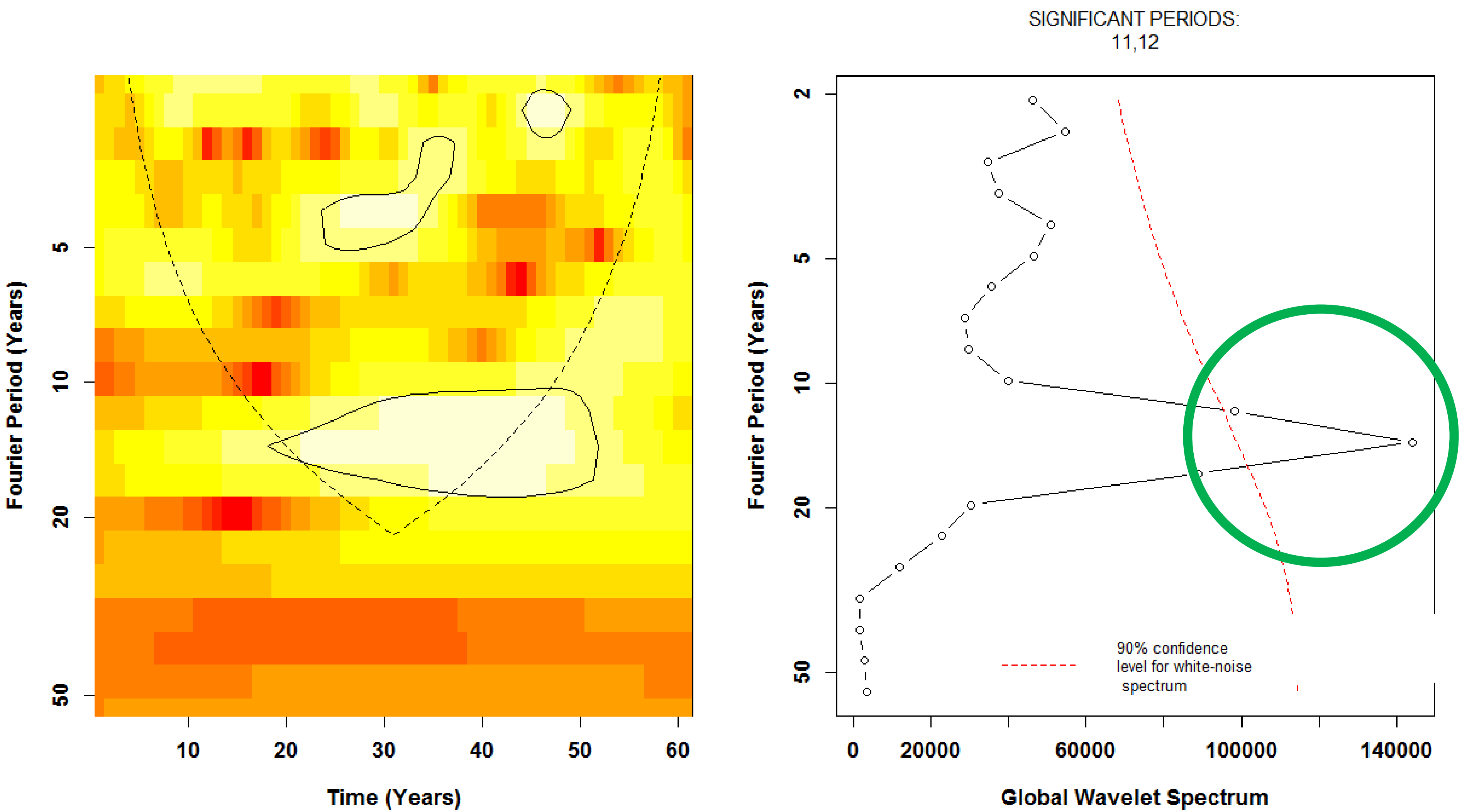
Schematic of SAC-SMA

VIC Basin	NSE From VIC (CA DWR)	NSE From VIC (UMASS)	NSE From SAC-SMA
FOL_I	0.82	0.84	**0.96**
LK_MC	0.89	0.90	**0.95**
N_MEL	0.81	0.84	**0.91**
MILLE	0.56	0.65	**0.92**
PRD_C	-1.20	0.37	**0.80**
N_HOG	-629	0.65	**0.96**
OROVI	0.88	0.88	**0.95**
DPR_I	0.76	0.82	**0.94**
SHAST	0.87	0.91	**0.97**
TRINI	-	0.82	**0.91**
SMART	-0.42	0.70	**0.91**

15-Year Low-Frequency Signal in California Precipitation

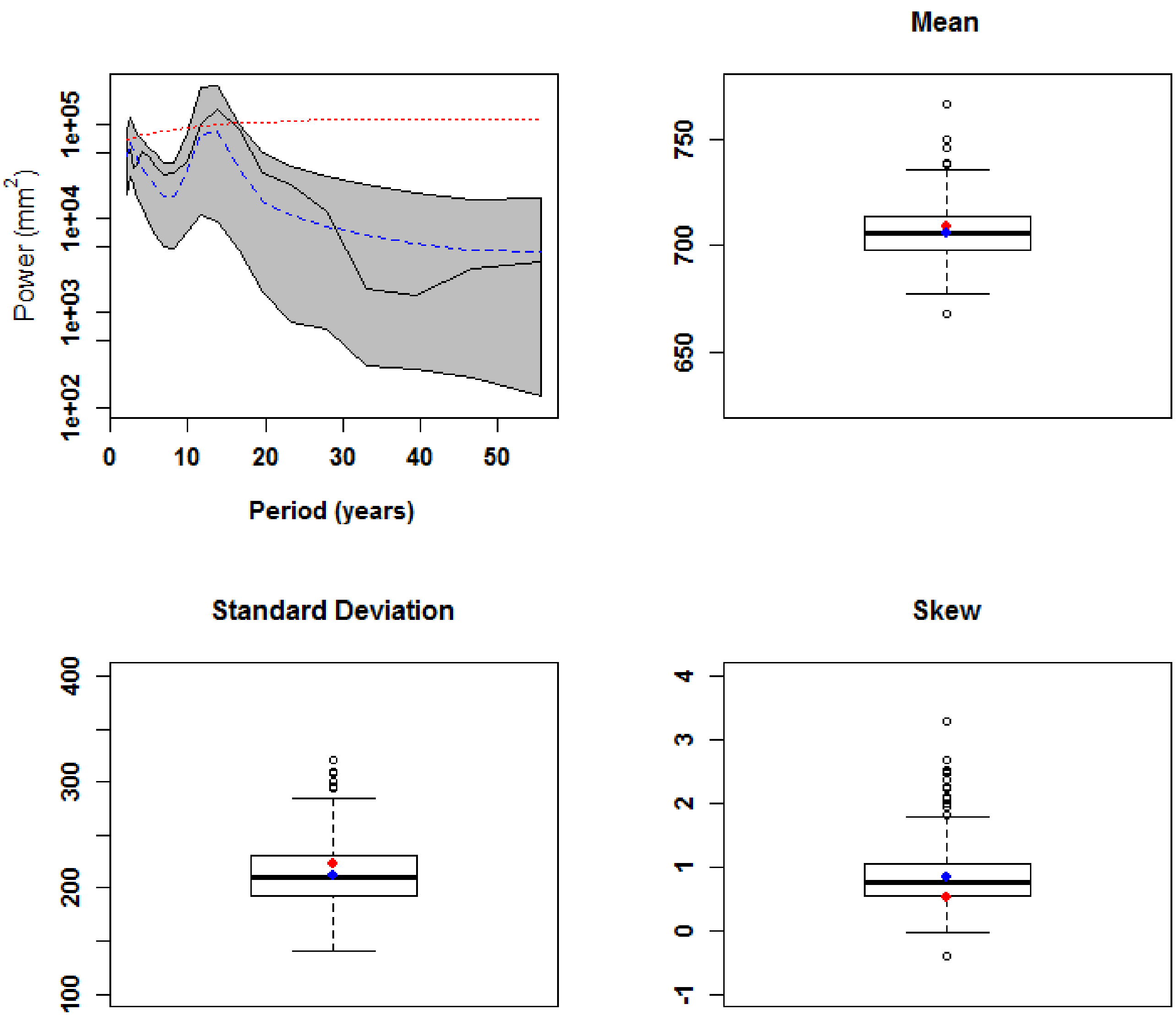
Consideration of physical basis

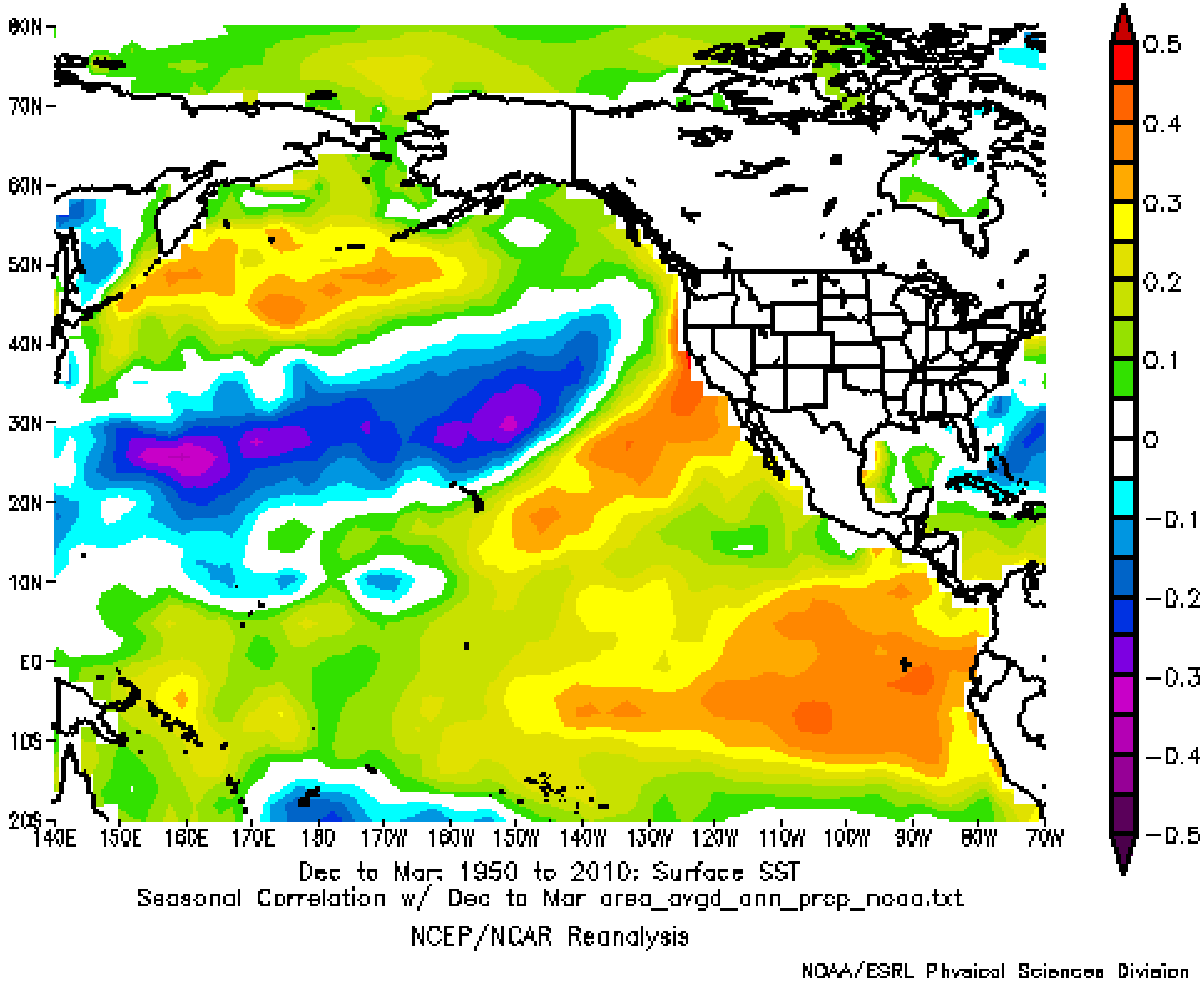
Wavelet Analysis of Area-Averaged Annual California Precipitation



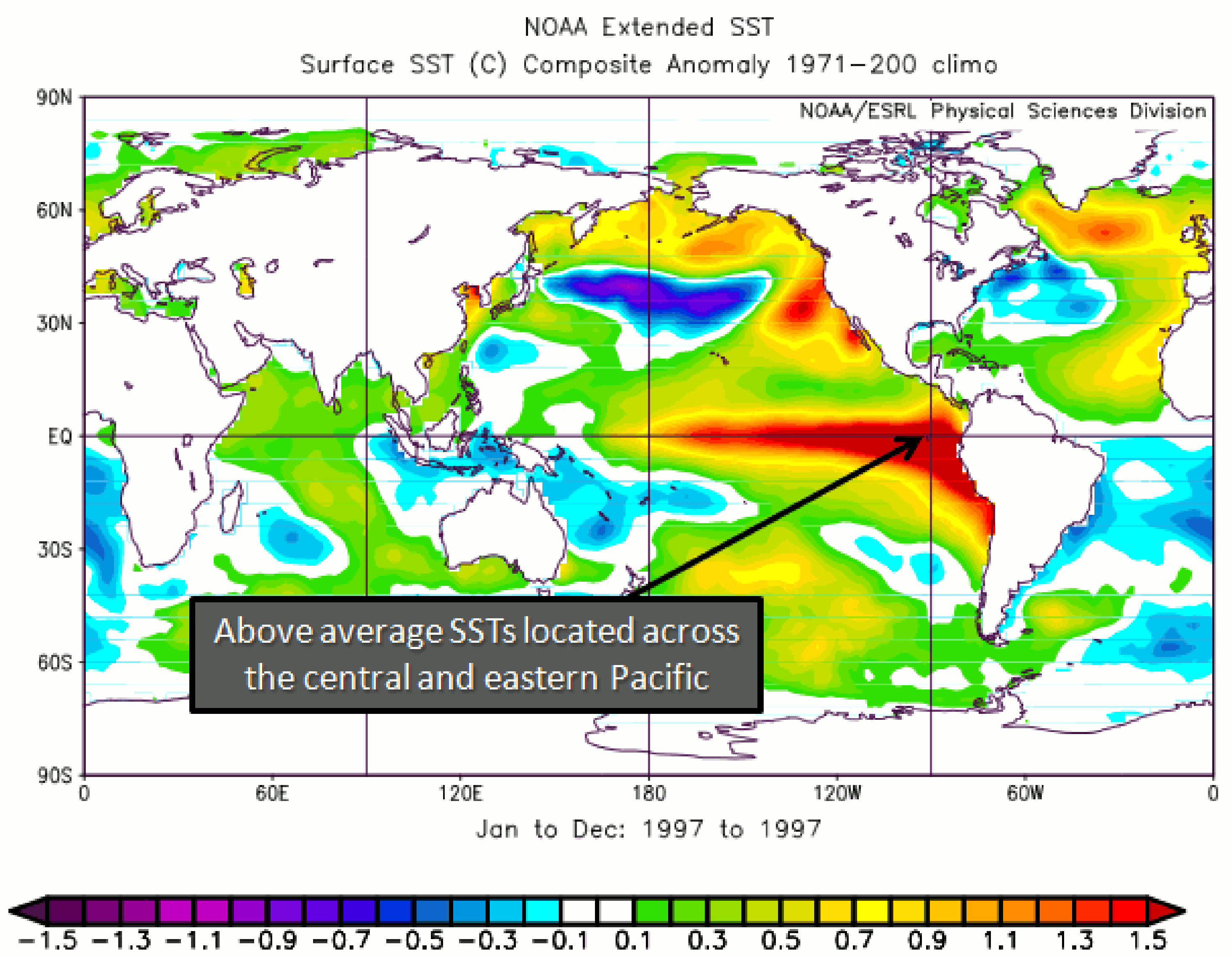
1950 2010

Our Wavelet AutoRegressive Model (statistics of 500 runs)





Correlations between annual area-averaged California precipitation and Dec-Mar SST in the Pacific from http://www.esrl.noaa.gov/psd/data/correlation/
ENSO-rainfall correlation calculated on our data (in R) is 0.21, approximately 90% significance.

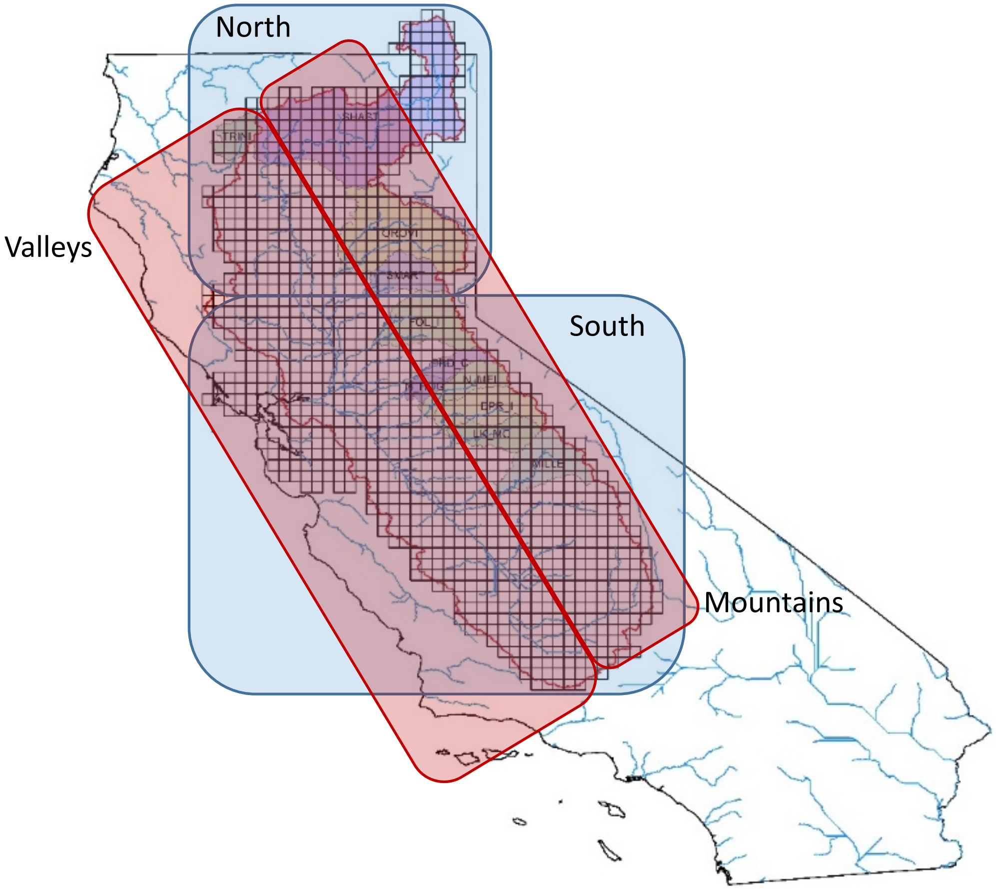


http://www.nc-climate.ncsu.edu/climate/patterns/ENSO.html

Next Steps

Next Steps

- Finish automation of CalLite
- Perform hydrologic model calibration experiments with initial runs of climate time series
- Run the hydrologic model and systems model together
- Present baseline (no climate change) plots to California DWR
- Design climate change experiments
- Begin climate change experiments
  - Run hydrologic model and systems model together many times to trace out climate response map



The current plan is to resample historical daily climate basin-wide in order to maintain spatial correlations.

Alternatively, we could re-sample in a more regionally-associated manner.

We could, for example, sample the north distinctly from the south (shown in blue regions) or the high altitudes distinctly from the low altitudes (shown in red regions).

This would be done using spatial correlations, and grounded in physical climate bases.